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A CRITIQUE OF PHOTOELECTRONIC COUNTERMEASURES

by

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A CRITIQUE OF PHOTOELECTRONIC COUNTERMEASURES

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ABSTRACT

In modern warfare, photoelectronic technology has been widely used by the military. With the rapid growth in photoelectronic technology, photoelectronic countermeasures technology has played an important role in such military applications as photoelectronic reconnaissance and counter reconnaissance, ECM and counter ECM. This article will provide a critique of the developments in photoelectronic countermeasures.

KEY WORDS: Photoelectronic reconnaissance, photoelectronic counter reconnaissance, Photoelectronic countermeasures, photoelectronic counter countermeasures.

I. Introduction

Photoelectronic countermeasures technology is the study of reconnaissance, countermeasures, weakening or destroying the effective use of the enemy's photoelectronic equipment and the comprehensive technical measures taken to protect ones own personnel and photoelectronic equipment. Since the first wars, there have been photoelectronic countermeasures technology. In ancient times warfare relied on human vision to detect the enemy, and to avoid detection, the enemy would employ such human sight countermeasures as the ruse of the Trojan horse to avoid detection, and placing dummies on war chariots[1]. In order to improve the effective distance of human vision, the visible light telescope was

invented, and was followed by technology to counter observation by human sight with a telescope, such as paint, camouflage and smoke screens. In 1934 the first infrared image converter tube appeared in Germany[2], allowing man to enter a new era where he could see at night and not only during the day. A number of infrared indicators appeared to deal with this type of active infrared night vision device. Since the appearance of the first laser in 1960, there has been extremely rapid growth in military laser applications such as laser range finders, guidance and blinders, as well as the corresponding appearance of such laser countermeasure technologies as laser reconnaissance warning, ECM aircraft, laser suppression, and laser protection. The appearance of the laser has added new content to countermeasure technology. Since the middle sixties, low-light night vision devices have been developed to the third generation, and since the primary operational wave bands of low-light night vision devices continues to be within the range of visible light, visible light countermeasure methods are still effective against them. Thermal imaging technology began in the sixties. Called forward looking infrared systems, it was first used on aircraft. It began to be widely used to equip units in the eighties. It has wide future applications in such areas as observation and sighting and guidance. Infrared countermeasures technology has appeared to deal with thermal imaging.

We can see from this that the developments in photoelectronic technology has spurred the development of the corresponding countermeasures, forming a new branch of science - photoelectronic countermeasures technology.

2. Photoelectronic reconnaissance technology

2.1. Visible light reconnaissance and warning technology

Visible light reconnaissance and warning technology was the first photoelectronic reconnaissance technology developed, and is the most widely employed technology. It was used on the battlefield as far back as the Second World War. It primarily includes: Periscopes, telescopic sights and television. It is primarily used to observe the battlefield, sight targets, firing correction and guidance. This type of technology is very mature, and the instruments are structurally simple and easy to use. However, because they operate in the wave band of 0.36~0.76μm, they are effected to a fairly high degree by the atmosphere. The developmental trend of this technology is stabilization of line of sight and use in combination with low light, laser and thermal imaging technologies to form an integrated instrument.

2.2. Night vision reconnaissance and warning technology

Night vision reconnaissance technology had its start in the thirties, and has gone through the developmental stages of active infrared, low-light and thermal imaging technologies. Most of these products have already been used to equip military units and have been used in battle with excellent combat results.

2.2.1. Active infrared technology

The first infrared image converter tube appeared in Germany in 1934. During World War Two, Germany was also the first to successfully develop an active infrared night vision device. After a number of improvements, its operational range was extended to 700 to 800 meters. This type of night vision device is not effected by

how bright the night, and the image is fairly clear. However, because it operates in an active mode, it is easily exposed.

2.2.2. Low-light technology

Since the sixties, direct vision low-light technology has been developed to three generations.

In the middle sixties a three stage coupled image intensifier appeared which used a fiber optical board as the input and output windows. This was the first generation low-light night vision device which was standardized in the seventies. It was fairly effective for observing over 100 meters. It operated in a passive mode, so had good concealability. It had high gain, and images were sharp and clear. However, it did not have good protection against intense light, and it was large and heavy.

In order to overcome the shortcomings of the first generation of low-light vision devices, the microchannel plate (MCP) was successfully developed in the seventies. The second generation of image intensifiers were developed using the MCP, and these intensifiers were used to make the second generation low-light night vision devices. Table 1 provides typical capabilities of the passive infrared and the first and second generation low-light night vision devices.

The second generation of low-light night vision devices overcame the shortcomings of the first generation. Their effective range was one and one-half times that of the first generation. They could also be used to make night vision binoculars. However, they used multi-alkali photocathodes, which do not take advantage of all of the night light.

Tab. 1 Typical performance of night vision equipment

1 国 别	2 型号(名称)	3 倍率/*	4 视场/°	5 作用距离/m		6 应用
				0.1 lx	0.01 lx	
7 俄罗斯	8 ТПН-1-49-23 主动红外瞄准镜	5.5	6	700~800		T-72
9 荷 兰	10 TS7TS 第一代微光瞄准镜	7	6	1200	800	T 系列 11
12 美 国	13 9896 第二代微光瞄准镜	5.2	10.6	1863	1095	M 系列 11

1. Country. 2. Model (nomenclature). 3. Power. 4. Field of view(°). 5. Operational range (m). 6. Application. 7. Russia. 8. TNP-1-49-23 active infrared sights. 9. Holland. 10. TS7TS first generation low-light sights. 11. Series. 12. United States. 13. 9896 Second generation low-light sights.

The negative electron affinity (NEA) photocathode was invented in the sixties to further improve the performance of low-light vision device. The third generation image intensifier was developed using this type of photocathode. This device is very sensitive (500-600μA/lm), and has a fairly high reaction at 0.9μm. It has a long life (500 to 10,000 hours). Resolution is high (32~46lp/mm). Its effective range is half again to twice that of the second generation. However, this device uses complex processes in manufacture, and the cost is fairly high. The photocathode is a place, and is restricted. Third generation low-light night vision devices have already been developed using this device.

2.3. Infrared reconnaissance and warning technology

Active infrared and low-light technology conduct reconnaissance by relying on target reflection. However, thermal imaging technology obtains an image through the differences in radiation of the different portions of the background objects themselves. Compared to active infrared and low-light vision, thermal imaging has the following advantages: it is basically an all-weather reconnaissance method, it operates in a passive mode,

it can penetrate smoke, fog, mist and snow, can recognize camouflage, is not effected by the strong lights on the battlefield or blinded by brilliant light jamming,a nd it has a fairly long effective range. At the present time thermal imaging systems have been developed to the second generation.

In 1964 the United States came out with the world's first live time display infrared imaging system. In 1976 it completed its universal component plan and in 1977 the United States developed the SPRITE detector. In 1980 it began to equip the military with opto-mechanical first generation thermal imaging systems which could recognize a typical target (2.3 by 2.3 meters) at a range of three kilometers.

Because the first generation thermal imaging systems used opto-mechanical scanning, they were large and heavy, and in addition, the operational range could not meed the requirements for infrared imaging guidance. In the late seventies they developed focal plane array technology. By 1983 there were major developments. The second generation thermal imaging systems which used focal plane arrays had an operational range of 1.4 to two times that of the first generation and used electronic scanning in place of opto-mechanical scanning, greatly reducing the overall weight. At the present time, prototypes of the second generation thermal imaging systems have already been developed and placed in trial use.

2.4. Laser reconnaissance and warning technology

Tab. 2. List of laser warning apparatus

1型 号	2 性 能 及 特 点	3现 状
RL1	4多平台载，由5个硅PIN光电二极管作探测器，9个发光二极管作方向显示，工作波长：0.66～1.1μm，覆盖空间：方位360°、角分辨率45°，$P_t \leq 10^{-3}$/h	5 已生产装备
RL2	6由一个硅PIN光电二极管作探测器，视场360°，不能分辨激光入射角，只能报警	7已生产装备
RL1*	8同RL1（购Simrad公司生产许可证）	9已生产装备
RL2*	10同RL2（购Simrad公司生产许可证）	11已生产装备
SAVIOUR*	12 车载，与雷达告警器组合共用处理显示器，激光告警传感头工作波长0.66～1.1μm，覆盖360°(方位)、−22.5°～+90°(俯仰)	13 已生产装备
453	14 多平台载，若干个分散的半球传感器，直径Φ25，深50，激光信号由光纤传感器传送到中央处理装置。工作波长：0.3～1.1μm。覆盖空间：360°(方位)，180°(俯仰)，角分辨率45°	高级发展阶段 15
1220*	16 多平台载，工作波长：0.35～1.1μm。覆盖空间：360°(方位)，−15°～+40°(俯仰)，角分辨率±22.5	17 已生产
AN/AVR-2	18 直升机载，与雷达告警器组合共用显示器，采用4套F-P干涉滤波器探测激光，覆盖空间360°，MTBF1800h，重7.5kg	陆军已采购275套 19
AN/ALR-89(V)	20 机载，与雷达报警器组合，4个激光传感器，一个激光分析器，威胁参数显示在76.2mm显示器上，声响报警信号送入载机的通信系统中	
ADELIE	21机载，4～8个传感器覆盖360°方位，工作波长：0.69～1.06μm，与雷达告警器共用显示屏	飞行试验22
HERALD	直升机载，指标不详 23	发展中 24
ALBERICH	与雷达报警器组合，激光工作波长：0.66～1.1μm 25	发展中 26
COLDS	多平台载，覆盖空间360°(方位)，±45°(俯仰)，角分辨率：方位±3°，俯仰任选。工作波长：0.4～2.0μm 27	预生产和外场试验中 28
LWS-20	直升机载，与雷达告警器组合，用于SPS-65机载自保护系统中，共用76.2mm机载显示屏，4个双激光传感器 27	30 已生产装备

1. Model. 2. Properties and characteristics. 3. Current status. 4. Carried on multiple platforms, Uses five silicon PIN photo-electronic diodes as the detectors, nine light emitting diodes as the directional indicators. Operational bandwidth is 0.66~1.1μm, sky coverage at 360 degrees. Angular resolution is 45°, $P_t \leq 10^{-3}$/h. 5. Produced and equipped. 6. Uses a silicon PIN photo-electronic diode as the detector, has a field of view of 360°, cannot determine laser angle of incidence, can only provide warning. 7. Already produced and equipped. 8. Same as RL1 (produced under license from Simrad Corporation). 9. Already produced and equipped. 10. Same as RL2 (produced under license from Simrad Corporation). 11. Already produced and equipped. 12. Truck model, uses the same processor and display as the radar warning device, laser warning sensor probe operates on a wavelength of 0.66~1.1μm,

aircraft. Uses in combination with radar warning device. Four laser sensors. One laser analyzer. Threat parameters displayed on 76.2 mm monitor. Sound warning signal sent through the aircraft communications system. 21. Airborne. Four to eight sensors cover 360° azimuth. Operating wavelength 0.69~1.06μm. Uses the same display screen as the radar warning device. 22. Flight testing. 23. Helicopter carried. Indices uncertain. 24. Under development. 25. Used together with radar warning device. Laser operational wavelength 0.66~1.1μm. 26. Under development. 27. Helicopter carried. Used together with radar warning device. Used on the SPS-65 airborne defense system. Uses the 76.2 mm airborne display screen. Four dual laser sensors. 30. Already produced and equipped.

Laser reconnaissance technology is divided into active and passive types. In the early sixties research began on an active laser reconnaissance system, and this was placed into use on the battlefield in Vietnam in the late sixties. In the seventies another surface active laser reconnaissance system was successfully developed which could obtain images and range up to several kilometers away. Research into passive laser reconnaissance began in the seventies. According to partial statistics, more than 20 different laser reconnaissance and warning equipment have been development, as many as six of which have been formally used to equip military units. Table 2 lists a number of different laser reconnaissance and warning equipment. At the present time laser reconnaissance and warning equipment include primarily the light spectrum recognition model and the coherent recognition model. The advantages of these two different models are shown in Table 3[3].

Tab. 3. Comparison between two types laser warning devices

1 类型	2 光谱识别		5 相干识别		8 散射探测
	3 非成像型	4 成像型	6 法布里-珀罗型	7 迈克尔逊型	
9 优点	结构简单,无需光学系统 视场大 10 灵敏度高 成本低	视场大,可凝视监视 虚警较低 11 角分辨率较高	灵敏度高 虚警低 12 能测激光波长 视场较大	虚警较低 13 角分辨率高 能测激光波长	无需直接拦截激光束 灵敏度较高 14 可凝视监视
15 缺点	角分辨率低 16 不能测激光波长 虚警较高	不能测激光波长 成本高 17 要用窄带滤光片	角分辨率较低 工艺难度大 成本高 18	视场小 19 成本较高 灵敏度低	光学系统难加工 要用窄带滤光片 不能分辨方向 20 对中远红外难以奏效

1. Type. 2. Light spectrum recognition. 3. Non imaging model. 4. Imaging model. 5. Coherent recognition. 6. Fabuli-Boluo (phonetic) model. 7. Michaelson model. 8. diffusion detection. 9. Advantages. 10. Structural simplicity, no optical system required. Large field of vision. High sensitivity. Low cost. 11. Large field of vision, fixed gaze monitoring possible. Low rate of false warnings. High angular resolution. 12. High sensitivity. Low rate of false warnings. Can measure laser wavelength. Fairly large field of vision. 13. Low rate of false warnings. High angular resolution. Can measure laser wavelength. 14. Does not require direct intercept of laser beam. Fairly high sensitivity. Fixed stare monitoring possible. 15. Shortcomings. 16. Low angular resolution. Cannot measure laser wavelength. High rate of false warnings. 17. Cannot measure laser wavelength. High cost. Must use narrow band optical filters. 18. Low angular resolution. Highly difficult industrial process. High cost. 19. Small field of vision. High cost. Low sensitivity. 20. Optical system difficult to process. Must use narrow band optical filter. Cannot determine azimuth. Not effective against medium and far infrared.

The operational wavelengths of these pieces of equipment are almost all between 0.45 and 2μm, and angular resolution is between 3° and 45°.

Light spectrum recognition model laser warning equipment can

be imaging or non-imaging. The non-imaging models commonly use one or a number of photoelectric diodes as detectors. Their structure is simple and they do not require optical systems. Their field of vision is large and detection sensitivity is high. They are also lo cost. However, azimuth resolution ability is poor. The imaging models usually use a wide angle fisheye lens and CCD photographic elements. They are characterized by high angular resolution, but their optical system is fairly complex. They usually are only able to operate on a single wavelength. It is difficult to make them small and they are expensive.

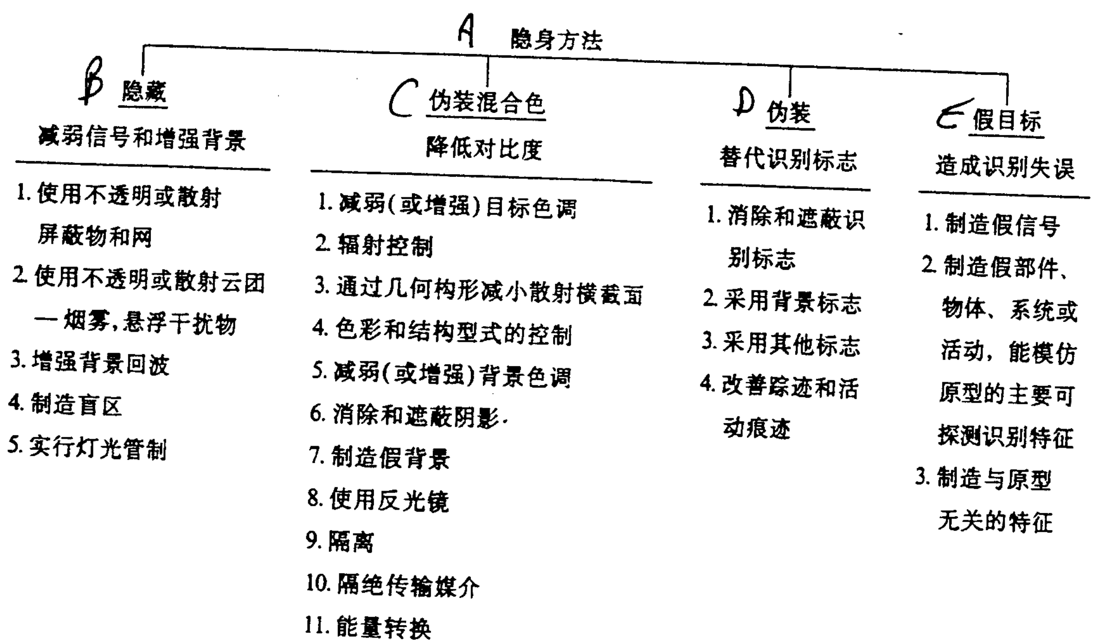
The coherent recognition method solves the light spectrum recognition problem of not being able to detect the laser wavelength. Laser light is highly time coherent, indicating time coherent physical properties - coherent length, is usually between several tenths of a millimeter and several dozen centimeters, while the coherent length of non-coherent light is only a few micrometers. Therefore, using an interferometer it is possible to detect and recognize laser light. This method has a strong recognition capability, and can detect the laser wavelength. It gives few false warnings. However, the industrial processes are complex, and the cost is high. The present developmental directions for laser warning technology i: expanding the warning wavelengths, from visible light and near infrared to medium and far infrared. Increasing directional accuracy, so angular resolution can reach 3° and to 1mrad. Improving the wavelength resolution capabilities. Developing CO_2 waveband laser guidance warning technology. Combining laser warning, infrared warning and radar warning into a photoelectronic warning system.

3. Photoelectric counter reconnaissance technology

Photoelectronic counter reconnaissance technology is primarily

methods used to change the optical characteristics of the target, achieving the goal of remaining undetected. Table 4 provides a number of different countermeasure methods.

Tab. 4. Methods of countermeasures



A. Stealth methods. B. Hiding. Reducing signals and intensifying background. 1. Use non transparent or diffusing screening material and nets. 2. Use non transparent or diffusing smoke screens, or suspension jamming materials. 3. Intensify background return waves. 4. Create a blind zone. 5. Restrict lights. C. Camouflage coloring. 1. Reduce (or intensify) target color contrast. 2. Control radiation. 3. Use geometric shapes to decrease scattering cross section. 4. Control colors and shapes. 5. Reduce (or intensify) background color contrast. 6. Eliminate or cover up shadows. 7. Create false background. 8. Use mirrors. 9. Isolate. 10. Eliminate color transmission mediums. 11. Energy conversion. D. Camouflage. Replace recognition signs. 1. Eliminate and cover recognition signs. 2. Use background signs. 3. Use other signs. 4. Remove signs of movement. E. Decoy targets. Create recognition errors. 1. Make false signals. 2. Make false parts, objects, systems or movements which can mimic the primary detectible recognition characteristics of the target. 3. Create characteristics unlike the target.

There are currently a large number of concealment methods. Here, we will only take about some of the concealment technologies.

Broadly speaking, camouflage is a type of stealth technology. Modern stealth technology began in the fifties, and by the sixties, stealth equipment was already being used to equip military units. In the eighties, with developments in science and technology, there were breakthrough developments in stealth technology.

3.1. Camouflage technology against visible light, infrared and laser reconnaissance

In order to reduce the probability of the target being detected by photoelectronic reconnaissance, the outside of the target can be painted with different sized spots and stripes. The colors and shapes used change with the season, terrain and surface objects.

The key to camouflage within any light spectrum is to match up the radiated energy of the surface of the target and the surrounding spectrum. To counter laser reconnaissance, one should reduce the reflected energy of the target as much as possible.

or moving targets, a freshly hewn plant or material indigenous to the combat zone can be used with good effects. However, these materials cannot be affixed to the target for an extended period and the plants will quickly dry up.

These problems can be avoided by using plastic camouflage on a moving target. It can camouflage moving targets as well as stationary ones. It can be used in the transition from moving to entering combat, as well as the other way around.

Using camouflage colors achieves good camouflage effects, and can be improved through using camouflage netting. It not only includes visual camouflage made of composite materials, but also includes thermal radiation camouflage netting. When using camouflage netting, time is required to put it on and take it off.

Current developmental trends of camouflage paints are: Further search for the mechanics of camouflage, such as the light spectrum reflection of the target and background, how differences in radiation and diffusion properties can be altered, transmission characteristics of the mediums between the target, background and photoelectronic detector, sensitivity and resolution limits of detectors, limitations of biological and psychological factors of the human eye, display system errors and jamming, limitations of light waves to detect or carry the target signals, solving the problem of wide light frequency camouflage, developing a more ideal camouflage pattern, especially thermal camouflage pattern.

3.2. Technology to reduce infrared radiation

This technology can allow the target's infrared radiation to be inhibited, causing the target surface temperature to tend to be the same as the background. Changing the normal location of the infrared radiation source, and thus changing the target's original radiation pattern, achieving the goal of concealment.

Since the mid seventies, many countries have been actively researching target infrared radiation inhibition technology, using the following specific methods:

3.2.1. Mingling with air

This method can cause the hot air flow to be cooled with the

surrounding air, but it is necessary to prevent any particles to be picked up to avoid hot suspension particles being sent out as continuous radiation. This method may have to be fan driven, which would make noise.

3.2.2. Using the natural convection currents of the air flow

This shifts the heat on vertical surfaces to the surrounding air. Conductivity is $8W/m^2$, temperature differential is 4°C. It does not require power, and can use fins to accelerate heat dispersal.

3.2.3. Forced convection of air currents

This shifts the heat from the surface to the surrounding air. Conductivity is $50W/m^2$. Temperature is 4°C. It has to be fan powered. It can use a heat converter to accelerate the transmission of heat.

3.2.4. Use of a honeycomb layer

Through heat conversion, it is possible to use airflow through a honeycomb layer to cool the target. It can absorb the infrared radiation coming from the hotter areas underneath, and can also absorb and transmit a large amount of irradiated laser energy.

3.2.5. Use of contained liquid

Pumping water through the hot air current to cause the exhaust (hot) gasses to be mixed with small drops of steam, thus achieving cooling. It requires power, and the cooling liquid has to be replenished. This method can achieve evaporative cooling of hot surfaces.

3.2.6. Use of heat-conducting pipes

Conduct heat over a fairly long distance, with a small temperature differential. It can be used to conduct the heat from a small high powered source to an enlarged heat exchanger with air fins for cooling and exhaust.

3.2.7. Use of liquid circuit

This can conduct heat over a fairly long distance. It requires a pump. It can also be used in a closed loop, but cooling liquid is easily lost.

3.2.8. Use of microscopic geometric cavities

The surface cavities can increase surface absorption of solar energy, can trap dirt, and increase the air flow exchange area.

3.2.9. Use of macroscopic geometric cavities

These can direct radiated or reflected energy in a predetermined direction. They will partially concentrate the irradiated solar energy, increase them and then reflecting them.

3.2.10. Use of insulating blankets

These effective limit radiation and thermal conduction along a chosen direction.

3.2.11. Adding an insulating cowling to the exhaust pipe or use the body of the target to cover it or place the exhaust pipe within the engine cooling air flow.

3.2.12. Improving the design of the engine combustion chamber to limit the infrared radiation of the products of combustion as much as possible

3.2.13. Adding additives to the motor fuel to inhibit engine smoke.

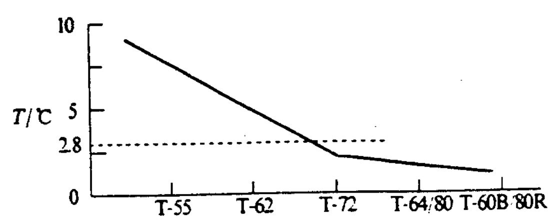
3.2.14. By using plasma technology to cover some metal engine parts with zirconium oxide ceramic coating, it is possible to lower the temperature of exposed metal.

3.2.15. By using skirting to shield the infrared radiation formed because of the heat generated by friction in moving targets.

3.2.16. Reduce the size of the target, reducing its infrared radiation.

Figure 1 shows the average temperature of the leading edge of the Russian T series tanks.

Fig. 1. Average temperature differential of Soviet tanks



4. Photoelectric countermeasures technology

Photoelectronic countermeasures technology is divided into passive counter measures and active countermeasures.

4.1. Photoelectric passive countermeasures technology

There are a great many photoelectric passive countermeasures technologies, including such things as smoke screens, aerosols, extinction shells, light spectrum conversion and water screens. Here we will only discuss smoke screen technology.

The military has used the simple, cheap smoke bomb as a photoelectronic countermeasure for a long time. The use of smoke bombs can keep the enemy's photoelectronic observation and sighting instruments and photoelectronic guided missiles from seeing the target or from tracking the target. The use of a smoke bomb can reduce the effectiveness of an anti-tank shell to 1/5 to 1/3. In the haze of a smoke screen, anti-tank guns and tank guns are rendered temporarily ineffective because the target cannot be seen. The smoke screens current used to equip units can counter visual systems from visible light (0.36~0.76μm) to near infrared (0.78~1.2μm), low-light vision devices, passive infrared night vision devices, point source infrared guided missiles and 1.06μm laser systems. A typical smoke screen bomb such s the M76 smoke screen bomb, can provide a smoke bomb 30 meters in front of a tank and 30 meters wide and 40 meters wide for one to three seconds. Its reliability is as high as 99[4]. The NATO smoke screen bomb has the ideal specifications shown in Table 5.

Tab. 5 Ideal specifications for smoke bombs

Field of fire	110-180°
Firing range	30-70 meters
Smoke height	7~12 meters
Maximum time to form smoke	3 seconds
Smoke screen duration	1 second

Current developmental trends for smoke screen bombs are: Further improvement of visible light and near infrared smoke screens, currently being developed far infrared smoke bombs, water

mist smoke screens which jam 10.6μm CO_2 lasers, Color mist smoke screens and green camouflage smoke screens.

4.2. Photoelectronic active countermeasures technology

Photoelectronic active countermeasures technology can be divided into deceptive type and suppression countermeasures technology.

4.2. Deception countermeasures technology

As infrared and laser guided missiles have appeared, it has generated a corresponding countermeasures technology. Employing this type of technology are primarily the infrared jammer, the infrared jamming bomb and the laser jammer. There are already some models which are used to equip military units such as the ALQ-144(V) infrared jamming equipment, the BAe infrared jammer, and the TSHY infrared jammer. The TSHY-1-7 vehicle carried infrared jammer can counter TOW, Hot, Milan, Dragon, Cobra and AT-3 antitank missiles. It can counter wavelengths of 0.7~1.2μm and 1.7~2.5μm. A single firing can cover an area of 20° azimuth, height of 4°, and axial light intensity of more than $2X10^5$cd.

There are currently three primary types of infrared jammers: the arc lamp type, the fuel oil type, and the electrothermal type.

The current developmental direction for infrared jammers is first, to strive to focus it on a certain direction in order to intensify its jamming capabilities, and second, to achieve omni-directional jamming, and third to achieve multiple wave length jamming.

The development of infrared guidance technology, and especially the appearance of infrared imaging guided missiles, have allowed infrared guided missiles to have the capability to differentiate between target radiation and to counter infrared jamming rounds. New infrared jamming bombs must be developed to meet this requirement. An example would the dual component bomb, the kinematic lure bomb, the tracer shell, the activated metal lure, the tank defensive close in lure, and the lure with heating element.

Infrared jamming shells are structurally simple and inexpensive, but requirements for firing times are quite stringent, and their effective time is short.

Laser jammers are being developed to deal with laser precision guided missiles. These use lasers to generate high energy directional light beam interference against the incoming missile.

4.2.2. Suppression type countermeasures technology

Suppression type countermeasures technology include primarily the blinding type and the destructive type.

Development of laser weapons began the year after the first laser appeared (1961). In the sixties a great deal of research was conducted on high energy lasers, sighting and tracking systems, atmospheric transmission effects and the mechanics of target destruction.In the seventies a prototype of a tactical laser weapon was successfully developed and went through a series of tests. In the eighties there was feasibility research, and the laser entered the initial engineering design stage. The prototype demonstration and engineering development stage. In the nineties several different systems are planned to be placed in service.

A strong laser can destroy such photoelectric sensors as night vision equipment, television cameras, thermal imagers, observation and sighting devices and target indicators, thus making it impossible for these devices to play an effective operational role. at the same time, strong lasers are also injurious to the human eye.

Strong laser light can be used in tactical air defense, suppressing observation and sighting devices, sealing up fire power and to increase ones own survivability and combat capability.

At the present time there are already the "Rainbow Fish" and the "Crown Prince" systems, the "High Photoelectronic jamming capsule", the "laser glare sighting device", the emerald "glare device", the "Cobra" and the "squeeze box" ranging/air defense system laser weapons systems. Their primary specifications are shown in Table 6.

Tab. 6 Specifications of laser weapons systems

Effective range	to blind photoelectronic sensor 6-8km suppress observation/sighting 300m-15km	
Wave length	1.06μm	0.53μm
Peak/average power	40MW/1000W	100MW/400W
System response time	3~5 seconds	
Beam scattering	0.2/0.1mrad	
Sighting/tracking precision	better than 1mrad	
maximum angular velocity	azimuth 90°/s, elevation 40°/s	
warning region	azimuth 0~360°, elevation 0~°	

4.3. Composite photoelectronic countermeasures technology

Composite use of passive and active jamming technology.

5. Photoelectronic counter countermeasures

Photoelectronic counter countermeasures technology was generated by the appearance of photoelectronic countermeasures. Like counter reconnaissance technology, it generally is not a piece of equipment using a single technology, but includes the design technology of photoelectronic equipment (such as laser range finders, indicators, photoelectronic guidance equipment, and photoelectronic reconnaissance equipment) and the control technology of the characteristics of tactical target indicator photoelectronic signals. Of course, it is also possible to use photoelectronic counter countermeasures technology to manufacture equipment for tactical missions.

There are many types of photoelectronic counter countermeasures technology. Countermeasures technology includes light gate, filter lens, rapid shutter, and attenuator. For lasers there are protective goggles and protective masks. There are highly reflective paint and enhanced surface structure. These individual technologies can also be used in combination to improve the countermeasures capability.

6. Developmental trends in photoelectronic countermeasures technology

In modern warfare combat requirements cannot be met by relying only of a few scattered pieces of photoelectronic countermeasures equipment. Therefore, it is necessary to enhance the overall photoelectronic countermeasures capability, so it is necessary to combine the use of the different types of photoelectronic countermeasures technology and to develop photoelectronic countermeasures systems.

Primarily multiple waveband photoelectronic surveillance and warning equipment which has counter surveillance capabilities and which has counter jamming capabilities, and combined with passive photoelectronic suppression and jamming equipment to form a comprehensive photoelectronic jamming system to facilitate dealing with various types of photoelectronic sensors at the same time.

The operational models of photoelectronic countermeasures equipment will run through the entire gambit of tactics and campaigns. They will penetrate to every aspect of the battlefield. They will involve all branches of the services and all types of forces, forming a tactical countermeasures system and be brought into the battlefield automated command, control, communications and information system, fusing it together with a large range of photoelectronic countermeasures to complete the campaign mission.

In the future, on the omnidirectional, in-depth, three dimensional, integrated "soft" and "hard" kill battlefield, there will appear photoelectronic countermeasure and photoelectronic counter countermeasure systems.